Attachment 2
FTHWG Report
January 2000

PROPOSAL
FOR
FAA ADVISORY CIRCULAR/JAA ADVISORY CIRCULAR JOINT RELATED TO JAR/FAR 25.21(g)

HANDLING CHARACTERISTICS AND PERFORMANCE IN APPENDIX C ICING CONDITIONS

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0 INTRODUCTION

This Advisory Circular {Advisory Circular Joint} provides guidance information on acceptable means of compliance related to performance and handling characteristics requirements of subpart B as affected by flight in the icing conditions defined in Appendix C of FAR 25 {JAR-25}. Like all Advisory Circular {Advisory Circular Joint} material, this guidance information is not mandatory and does not constitute regulations. It is derived, in large part, from previous experience in finding compliance with the airworthiness requirements and describes methods and procedures found to be acceptable by that experience. Where mandatory terms such as "shall" and "must" are used in this Advisory Circular {Advisory Circular Joint}, these terms apply only to applicants who seek to demonstrate compliance by use of the specific methods described herein, while that method of compliance is itself not mandatory.

The guidance information is presented in three chapters plus three appendices.

Chapter 1 explains the various performance and handling requirements in relation to the flight conditions that are relevant for determining the shape and texture of ice accretions for the airplane in the atmospheric conditions of FAR 25 {JAR-25}, Appendix C.

Chapter 2 describes acceptable methods and procedures that an applicant may use to show that an airplane meets these requirements. Depending on the design features of a specific airplane as discussed in Appendix 3 of this AC, its similarity to other types or models, and the service history of those types or models, some judgment will often be necessary for determining that any particular method or procedure is adequate for showing compliance with a particular requirement. These factors are also discussed in Chapter 2. Any alternate method or procedure proposed by the applicant should be given due consideration. Applicants are encouraged to develop more efficient and less costly methods of achieving the objectives of the applicable requirements of FAR 25 {JAR-25}.

Chapter 3 provides an acceptable flight test program where flight testing is selected by the applicant and agreed to by the Authority as being the primary means of compliance.

The three appendices provide additional reference material associated with ice accretion, artificial ice shapes, and airplane design features.

1 REQUIREMENTS GUIDANCE

1.1 General

Chapter 1 provides guidance for showing compliance with Subpart B requirements for flight in icing conditions.

Operating rules for large and turbine-powered multiengine airplanes (e.g. FAR 91.527, FAR 121.629, and JAR-OPS1.345) require that the airplane is free of any significant ice contamination at the beginning of the take-off roll due to application of appropriate ice removal and ice protection procedures during flight preparation on the ground.

Appendix C to FAR/JAR 25 defines the ice accretions to be used in showing compliance with FAR/JAR 25.21(g) and (h).. Appendix 1 of this AC provides details on ice accretions including accounting for delay in the operation of the ice protection system and consideration of ice detection systems.

Certification experience has shown that it is not necessary to consider ice accumulation on the propeller, induction system or engine components of an inoperative engine for handling qualities substantiation. Similarly, the mass of the ice need not normally be considered.

Flight in icing conditions includes operation of the airplane after leaving the icing conditions but with ice accretion remaining on the critical surfaces of the airplane.

1.2 Proof of Compliance (FAR/JAR 25.21(g))

Demonstration of compliance with certification requirements for flight in icing conditions may be accomplished by any of the means discussed in paragraph 2.1.

Certification experience has shown that airplanes of conventional design do not require additional detailed substantiation of compliance with the requirements of FAR/JAR 25.23, 25.25, 25.27, 25.29, 25.31, 25.231, 25.233, 25.235, 25.253(a) and (b), and 25.255 for flight in icing conditions or with ice accretions.

Where normal operation of the ice protection system results in changing the stall warning system and/or stall identification system activation settings, it is acceptable to establish a procedure to return to the non icing settings when it can be demonstrated that the critical wing surfaces are free of ice accretion.

1.3 Propeller Speed and Pitch Limits (FAR/JAR 25.33)

Certification experience has shown that it may be necessary to impose additional propeller speed limits for operations in icing conditions.

1.4 Performance - General (FAR/JAR 25.101)

1.4.1 The propulsive thrust available for each flight condition must be appropriate to the airplane operating limitations and normal procedures for flight in icing conditions. In general, it is acceptable to determine the propulsive thrust available by suitable analysis, substantiated when required by appropriate flight tests (e.g., when determining the thrust available after 8 seconds for FAR/JAR 25.119). The following aspects should be considered:

(a) Operation of induction system ice protection

(b) Operation of propeller ice protection

(c) Operation of engine ice protection

(d) Operation of airframe ice protection system.

1.4.2 The following should be considered when determining the change in performance due to flight in icing conditions:

(a) Thrust loss due to ice accretion on propulsion system components with normal operation of the ice protection system, including engine induction system and/or engine components, and propeller spinner and blades.

(b) The incremental airframe drag due to ice accretion with normal operation of the ice protection system.

(c) Changes in operating speeds due to flight in icing conditions.

1.4.3 Certification experience has shown that any increment in drag (or decrement in thrust) due to the effects of ice accumulation on the landing gear, propeller, induction system and engine components may be determined by analysis.

1.4.4 Apart from the use of appropriate speed adjustments to account for operation in icing conditions, any changes in the procedures established for take-off, balked landing, and missed approaches should be agreed.

1.4.5 Performance associated with flight in icing conditions is applicable after exiting icing conditions until the ice protection systems are selected "off" and the airplane critical surfaces are free of ice accretion.

1.5 Stalling speed (FAR/JAR 25.103)

Certification experience has shown that for airplanes of conventional design it is not necessary to make a separate determination of the effects of Mach number on stall speeds for the airplane with ice accretions.

1.6 Failure Conditions (FAR/JAR 25.1309)

1.6.1 The failure modes of the ice protection system and the resulting effects on airplane handling and performance should be analyzed in accordance with FAR/JAR 25.1309. In determining the probability of a failure condition, it should be assumed that the probability of entering icing conditions is one.

1.6.2 For probable failure conditions that are not annunciated to the crew, the guidance in this Advisory Circular for a normal condition is applicable with the Failure Ice configuration.

1.6.3 For probable failure conditions that are annunciated and the associated procedure does not require the airplane to exit icing conditions, the guidance in this Advisory Circular for a normal condition is applicable with the Failure Ice configuration.

1.6.4 For probable failure conditions that are annunciated to the crew, and the associated operating procedure requires the airplane to leave the icing conditions as soon as practicable, it should be shown that the airplane is capable of continued safe flight and landing with the "Failure ice" accretion defined in Appendix C. The operating procedures and related speeds should provide an adequate operating envelope and acceptable performance and handling characteristics to ensure continued safe flight and landing.

1.6.5 For failure conditions that are improbable but not extremely improbable, the analysis and substantiation of continued safe flight and landing, in accordance with FAR/JAR 25.1309, should take into consideration whether annunciation of the failure is provided and the associated operating procedures and speeds to be used following the failure condition.

1.7 Flight-related Systems

In general, systems aspects are covered by the applicable systems and equipment requirements in other Subparts of FAR/JAR 25, and associated guidance material. However, certification experience has shown that other flight related systems aspects should be considered when determining compliance with the flight requirements of Subpart B. For example, the following aspects may be relevant :

(a) The ice protection systems may not anti-ice or de-ice properly at all thrust/power settings. This may result in a minimum power setting for operation in icing conditions which affects descent and/or approach capability.

(b) Ice blockage of control surface gaps and/or freezing of seals causing increased control forces, control restrictions or blockage.

(c) Airspeed, altitude and/or angle of attack sensing errors due to ice accretion forward of the sensors (e.g. radome ice). Dynamic pressure ("q") operated feel systems using separate sensors may also be affected.

(d) Ice blockage of unprotected inlets and vents which may affect the propulsive thrust available, aerodynamic drag, powerplant control or flight control.

(e) Operation of stall warning and stall identification reset features for flight in icing conditions, including the effects of failure to operate.

(f) Operation of icing condition sensors, ice accretion sensors and automatic or manual activation of ice protection systems.

(j) Automatic flight control systems operation.

(l) Installed thrust. This includes operation of ice protection systems when establishing acceptable thrust setting procedures, control, stability, lapse rates, rotor speed margins, temperature margins, Automatic Takeoff Thrust Control System (ATTCS) operation, and thrust lever angle functions.

1.8 Airplane Flight Manual (JAR/FAR 25.1581)

1.8.1 Limitations

(a) Where limitations are required to ensure safe operation in icing conditionsthese limitations shall be stated in the AFM.

(b) The Limitations section of the AFM should include, as applicable, a statement similar to the following: "In icing conditions the airplane must be operated, and its ice protection systems used as described in the operating procedures section of this manual. Where specific operational speeds and performance information have been established for such conditions, this information must be used."

1.8.2 Operating Procedures

(a) AFM operating procedures for flight in icing conditions should include normal operation of the airplane including operation of the ice protection system and operation of the airplane following ice protection system failures. Any changes in procedures for other airplane system failures that affect the capability of the airplane to operate in icing conditions should be included.

(b) Normal operating procedures provided in the AFM should reflect the procedures used to certify the airplane for flight in icing. This includes configurations, speeds, ice protection system operation, power plant and systems operation, for take-off, climb, cruise, descent, holding, go-around, and landing.

(c) Abnormal operating procedures should include the procedures to be followed in the event of annunciated ice protection system failures and suspected unannunciated failures. Any changes to other abnormal procedures contained in the AFM, due to flight in icing, should also be included.

1.8.3 Performance Information

Performance information, derived in accordance with Subpart B, must be provided in the AFM for all relevant phases of flight.

2 ACCEPTABLE MEANS OF COMPLIANCE - GENERAL

2.1 General

Chapter 2 describes acceptable methods and procedures that an applicant may use to show that an airplane meets the performance and handling requirements of subpart B in the atmospheric conditions of Appendix C to FAR/JAR-25.

Compliance with FAR/JAR 25.21(g) should be shown by one or more of the methods listed in this section, as agreed to with the Certification Authority.

The compliance process should address all phases of flight, including take-off, climb, cruise, holding, descent, landing and go-around as appropriate to the airplane type considering its typical operating regime.

The design features included in Appendix 3 should be considered when determining the extent of the substantiation program.

Appropriate means for showing compliance include:

<u>Flight Testing</u>
Flight testing in dry air using artificial ice shapes or with ice shapes created in natural icing conditions.

<u>Wind Tunnel Testing and Analysis</u>
An analysis of results from wind tunnel tests with artificial ice shapes.

<u>Engineering Simulator Testing and Analysis</u>
An analysis of results from engineering simulator tests.

<u>Engineering Analysis</u>
An analysis which may include the results from executing an agreed computer code.

<u>Ancestor Airplane Analysis</u>
An analysis of results from a closely related ancestor airplane.

Various factors that affect ice accretion on the airframe with an operative ice protection system and with ice protection system failures are discussed in Appendix 1.

An acceptable methodology to obtain agreement on the artificial ice shapes is given in Appendix 2. This Appendix also provides the different types of artificial ice shapes to be considered.

2.2 Flight Testing

2.2.1 General

The extent of the flight test program should consider the results obtained with the non-contaminated airplane and the design features of the airplane as discussed in Appendix 3 of this AC.

It is not necessary to repeat an extensive performance and flight characteristics test program on an airplane with ice accretion. A suitable program, which is sufficient to demonstrate compliance with the requirements, can be established from experience with airplanes of similar size, review of the ice protection system design, control system design, wing design, horizontal and vertical stabilizer design, performance characteristics and handling characteristics of the non-contaminated airplane. In particular it is not necessary to investigate all weight and center of gravity combinations when results from the non-contaminated airplane clearly indicate the most critical combination to be tested. It is not necessary to investigate the flight characteristics of the aircraft at high altitude (i.e. above the upper limit specified in Appendix C). An acceptable flight test program is given in Chapter 3.

Certification experience has shown that tests are usually necessary to evaluate the consequences of ice protection system failures on handling characteristics and performance and to demonstrate continued safe flight and landing.

2.2.2 Flight Testing Using Approved Artificial Ice Shapes

The performance and handling tests may be based on flight testing in dry air with agreed artificial ice shapes.

Additional limited flight tests should be conducted in natural icing conditions, which are discussed in 2.2.3.

2.2.3 Flight Testing In Natural Icing Conditions

(a) Where flight testing in natural atmospheric icing conditions is the primary means of compliance, the conditions should be measured and recorded. The tests should ensure good coverage of Appendix C conditions and, in particular, the critical conditions. The conditions for accreting ice (including the icing atmosphere, configuration, speed and duration of exposure) should be agreed with the Authority.

(b) Where flight testing with artificial ice shapes is the primary means of compliance, additional limited flight tests should be conducted in measured natural icing conditions. The objective of these tests is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes. For some derivative airplanes with similar aerodynamic characteristics as the ancestor, it may not be necessary to carry out additional flight test in measured natural icing conditions if such tests have been already performed with the ancestor.

2.3 Wind Tunnel Testing and Analysis

Analysis of the results of dry air wind tunnel testing of models with artificial ice shapes as defined in Part 2 of Appendix C to FAR Part 25 may be used to substantiate the performance and handling characteristics.

2.4 Engineering Simulator Testing and Analysis

The results of an engineering simulator analysis of an airplane that includes the effects of the ice accretions as defined in Part 2 of Appendix C to FAR Part 25 may be used to substantiate the handling characteristics. The data used to model the effects of ice accretions for the engineering simulator may be based on results of dry air wind tunnel tests, flight tests, computational analysis, and engineering judgment.

2.5 Engineering Analysis

An engineering analysis that includes the effects of the ice accretions as defined in Part 2 of Appendix C to FAR Part 25 may be used to substantiate the performance and handling characteristics. The effects of the ice shapes used in this analysis may be determined by an analysis of the results of dry air wind tunnel tests, flight tests, computational analysis, engineering simulator analysis and engineering judgment.

2.6 Ancestor Airplane Analysis

An ancestor airplane analysis that includes the effect of the ice accretions as defined in Part 2 of Appendix C to FAR Part 25 may be used to substantiate the performance and handling characteristics. This analysis should consider the similarity of the configuration, operating envelope, performance and handling characteristics, and ice protection system of the ancestor airplane.

The analysis may include flight test data, dry air wind tunnel test data, icing tunnel test data, engineering simulator analysis, service history, and engineering judgment.

3 ACCEPTABLE MEANS OF COMPLIANCE - FLIGHT TEST PROGRAM

3.1 General

Chapter 3 provides an acceptable flight test program where flight testing is selected by the applicant and agreed to by the Authority as being the primary means for showing compliance.

Where an alternate means of compliance is proposed for a specific paragraph in Chapter 3 it should enable compliance to be shown with at least the same degree of confidence as flight test would provide (see FAR/JAR 25.21(a)(1)).

This test program is based on the assumption that the applicant will choose to use "Holding ice" for the majority of the testing on the basis that this is the most conservative shape. Where this is not so, the applicant may choose to use an ice shape appropriate to the particular phase of flight.

3.2 Stalling Speed (FAR/JAR 25.103)

3.2.1 The stall speed for intermediate high lift configurations can normally be obtained by interpolation. However if a stall identification system (e.g. stick pusher) firing point is set as a function of the high lift configuration and/or the firing point is reset for icing conditions, or if significant configuration changes occur with extension of trailing edge flaps (such as wing leading edge high-lift device position movement), additional tests may be necessary.

3.2.2 The following represents an acceptable test program subject to the provisions outlined above:

(a) Forward center of gravity position appropriate to the configuration

(b) Normal stall test altitude

(c) Trim at an initial speed of 1.13 to 1.30 V_{SR}. Decrease speed until an acceptable stall identification is obtained.

(1) High lift devices retracted configuration, "Final Take-off ice"

(2) High lift devices retracted configuration, "En-route ice"

(3) Holding configuration, "Holding ice"

(4) Lowest lift take-off configuration, "Holding ice"

(5) Highest lift take-off configuration, "Take-off ice"

(6) Highest lift landing configuration, "Holding ice"

3.3 Accelerate-stop Distance (FAR/JAR 25.109)

The effect of any increase in V_1 due to take-off in icing conditions may be determined by a suitable analysis.

3.4 Take-off Path (FAR/JAR 25.111)

If V_{SR} in the configuration defined by FAR/JAR 25.121(b) with the "Takeoff ice" accretion defined in Appendix C exceeds V_{SR} for the same configuration without ice accretions by more than the greater of 3 knots or 3%, the take-off demonstrations should be repeated to substantiate the speed schedule and distances for take-off in icing conditions. The effect of the take-off speed increase, thrust loss and drag increase on the take-off path may be determined by a suitable analysis.

3.5 Landing Climb: All-engines-operating (FAR/JAR 25.119)

The following represents an acceptable test program:

(a) "Holding ice"

(b) Forward center of gravity position appropriate to the configuration

(c) Highest lift landing configuration, landing climb speed no greater than V_{REF}

(d) Stabilize at the specified speed and conduct 2 climbs or drag polar checks as agreed with the Authority.

3.6 Climb: One-engine-inoperative (FAR/JAR 25.121)

The following represents an acceptable test program:

(a) Forward center of gravity position appropriate to the configuration

(b) Stabilize at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs in each configuration or drag polar checks substantiated for the asymmetric drag increment as agreed with the Authority.

(1) High lift devices retracted configuration, final take-off climb speed, "Final Take-off ice"

(2) Lowest lift take-off configuration, landing gear retracted, V_2 climb speed, "Take-off ice"

(3) Approach configuration appropriate to the highest lift landing configuration, landing gear retracted, approach climb speed, "Holding ice".

3.7 En-route Flight Path (FAR/JAR 25.123)

The following represents an acceptable test program:

(a) "En-route ice"

(b) Forward center of gravity position appropriate to the configuration

(c) En-route configuration and climb speed

(d) Stabilize at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs or drag polar checks substantiated for the asymmetric drag increment as agreed with the Authority.

3.8 Landing (FAR/JAR 25.125)

The effect of landing speed increase on the landing distance may be determined by a suitable analysis.

3.9 Controllability and Maneuverability - General (FAR/JAR 25.143 and 25.177)

3.9.1 A qualitative and quantitative evaluation is usually necessary to evaluate the airplane's controllability and maneuverability. In the case of marginal compliance, or the force limits or stick force per g limits of FAR /JAR 25.143 being approached, additional substantiation may be necessary to establish compliance. In general it is not necessary to consider separately the ice accretion appropriate to take-off and en route as the "Holding ice" is usually the most critical.

3.9.2 The following represents an acceptable test program for general controllability and maneuverability subject to the provisions outlined above:

(a) Holding ice

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at specified speed. Conduct 30 degrees banked turns left and right with rapid reversals. Conduct pull up to 1.5g (except that this may be limited to 1.3g at V_{REF}) and pushover to 0.5g (except that the pushover is not required at V_{MO} and V_{FE}). Deploy and retract deceleration devices at the specified speed.

(1) High lift devices retracted configuration: 1.3 V_{SR}, V_{MO} or 250 KIAS whichever is less.

(2) Lowest lift take-off configuration : 1.3 V_{SR} and V_{FE} or 250 knots IAS whichever is less.

(3) Highest lift landing configuration : V_{REF} and V_{FE} or 250 knots IAS whichever is less.

(d) Lowest lift take-off configuration: 1.13 V_{SR} or $V_{2\,MIN}$, one engine inoperative (simulated), 30 degrees banked turns left and right with normal turn reversals and, in wings-level flight, a 5 knot speed decrease and increase

(e) Approach and go-around with all engines operating using the recommended procedure

(f) Approach and go-around with one engine inoperative (simulated) using the recommended procedure

(g) Approach and landing using the recommended procedure.. In addition satisfactory controllability should be demonstrated during a landing with V_{REF} minus 5 knots. These tests should be done at heavy weight and forward center of gravity.

(h) Approach and landing with one engine inoperative (simulated) using the recommended procedure.

3.9.3 The following represents an acceptable test program for compliance with controllability requirements in low g maneuvers and in sideslips.

For pushover maneuvers, it should be shown that the airplane is controllable down to zero g or the lowest load factor obtainable if limited by elevator power. It should be shown that a push force is required down to + 0.5 g load factor, and that it is possible to promptly recover from the maneuver without exceeding 50 pounds pull control force.

Minority Positions

FAA, JAA, ALPA (zero-g pushover disagreement):

For pushover maneuvers, a push force should be maintained down to zero g or the lowest load factor obtainable if limited by elevator power.

Transport Canada

It should be shown that a push force is required down to + 0.25 g load factor, and that it is possible to promptly recover from the maneuver without exceeding 50 pounds pull control force.

[For details of Minority Positions, refer to the Draft NPRM.]

For sideslips, changes in longitudinal control force to maintain speed with increasing sideslip should be progressive with no reversals or sudden discontinuities (see paragraph 3.15.1).

(a) "Holding ice". For airplane with unpowered elevators these tests should also be performed with "Sandpaper ice"

(b) Medium to light weight, the most critical of aft or forward center of gravity position, symmetric fuel loading

(c) With the airplane in trim, or as nearly as possible in trim, at the specified trim speed, perform a continuous maneuver (without changing trim) to reach zero g normal load factor or, if limited by elevator control authority the lowest load factor obtainable, at the target speed.

(1) Highest lift landing configuration at idle thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not more than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not less than V_{FE} - 20 knots.

(2) Highest lift landing configuration at go-around thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not more than 1.23 V_{SR}, or:

- Trim speed V_{FE}, target speed not less than V_{FE} - 20 knots.

(d) Conduct steady heading sideslips to full rudder authority, 180 lb. rudder force or full lateral control authority (whichever comes first), with highest lift landing configuration, trim speed 1.23 V_{SR}, and thrust for -3 degrees flight path angle.

3.9.4 The following represents an acceptable test program for compliance with controllability requirements with the ice accretion prior to normal operation of the ice protection system.

(a) Where the ice protection system is activated as described in A1.2.3(a), paragraphs 3.9.1, 3.9.2 and 3.9.3 are applicable with the ice accretion prior to normal system operation.

(b) Where the ice protection system is activated as described in A1.2.3 (b), (c), (d) or (e), it is acceptable to demonstrate adequate controllability with the ice accretion prior to normal system operation, as follows:

With the airplane in the prescribed configuration, trim at the specified speed. Conduct pull up to 1.5g and pushover to 0.5g without longitudinal control force reversal.

(1) High lift devices retracted configuration (or holding configuration if different), holding speed, thrust for level flight

(2) Landing configuration, V_{REF} for non icing conditions, thrust for landing approach (limit pull up to stall warning).

3.10 Longitudinal Control (FAR/JAR 25.145)

3.10.1 No specific quantitative evaluations are required for determining compliance with FAR/JAR 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated.

3.10.2 The following represents an acceptable test program for compliance with FAR/JAR 25.145(a):

(a) Holding ice

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at 1.3 V_{SR}. Reduce speed using elevator control to stall warning plus one second and demonstrate prompt recovery to the trim speed using elevator control.

(1) High lift devices retracted configuration, maximum continuous thrust

(2) Maximum lift landing configuration, maximum continuous thrust.

3.11 Directional and Lateral Control (FAR/JAR 25.147)

Qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated.

3.12 Trim (FAR/JAR 25.161)

Qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated.

3.13 Stability - General (FAR/JAR 25.171)

Qualitative evaluations should be combined with the other testing. Any tendency to change speed when trimmed or requirement for frequent trim inputs should be specifically investigated.

3.14 Demonstration of Static Longitudinal Stability (FAR/JAR 25.175)

3.14.1 Each of the following cases should be tested. In general, it is not necessary to test the cruise configuration at low speed (FAR/JAR 25.175(b)(2)) or the cruise configuration with landing gear extended (FAR /JAR25.175(b)(3)), nor is it necessary to test at high altitude. Although the maximum speed for substantiation of stability characteristics is the lower of 300 knots CAS or V_{FC}, the maximum speed for demonstration can be limited to 280 knots CAS provided that the stick force gradient can be satisfactorily extrapolated to 300 knots CAS or V_{FC} (e.g. there is no gradient decrease with increasing speed).

3.14.2 The following represents an acceptable test program.

(a) "Holding ice"

(b) High landing weight, aft center of gravity position, symmetric fuel loading

(c) Trim at initial specified speed and other conditions as stated in the requirement.

(1) Climb with high lift devices retracted, Trim at 1.3 V_{SR}

(2) Cruise with high lift devices retracted, Trim at V_{MO} or 250 knots CAS, whichever is lower

(3) Approach with the high lift devices in the approach position appropriate to the highest lift landing configuration, trim at 1.3 V_{SR}

(4) Landing with the highest lift landing configuration, trim at 1.3V_{SR}.

3.15 Static Directional and Lateral Stability (FAR/JAR 25.177)

3.15.1 Compliance should be demonstrated using steady heading sideslips to show compliance with directional and lateral stability. The maximum sideslip angles obtained should be recorded and may be used to substantiate a crosswind value for landing (see paragraph 3.19).

3.15.2 The following represents an acceptable test program for static directional and lateral stability:

(a) "Holding ice"

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at specified speed. Conduct steady heading sideslips to full rudder authority or 180 lb. rudder pedal force or full lateral control authority (whichever comes first).

(1) High lift devices retracted configuration: Trim at best rate-of-climb speed but need not be less than 1.3 V_{SR}

(2) Lowest lift take-off configuration: Trim at the all-engines-operating initial climb speed

(3) Highest lift landing configuration: Trim at V_{REF}.

3.16 Dynamic Stability (FAR/JAR 25.181)

Provided that there are no marginal compliance aspects with the non-contaminated airplane, it is not necessary to demonstrate dynamic stability in specific tests. Qualitative evaluations should be combined with the other testing. Any tendency to sustain oscillations in turbulence or difficulty in achieving precise attitude control should be investigated.

3.17 Stall Demonstration (FAR/JAR 25.201)

3.17.1 Sufficient stall testing should be conducted to demonstrate that the stall characteristics comply with the requirements. In general, it is not necessary to conduct a stall program which encompasses all weights, center of gravity positions (including lateral asymmetry), altitudes, high lift configurations, deceleration device configurations, straight and turning flight stalls, power off and power on stalls. Based on a review of the stall characteristics of the non-contaminated airplane, a reduced test matrix can be established. However, if the stall characteristics with ice accretion show a significant difference from the non-contaminated airplane, or testing indicates marginal compliance, or a stall identification system (e.g. stick pusher) is required to be reset for icing conditions, additional tests may be necessary.

3.17.2 The following represents an acceptable test program subject to the provisions outlined above. Turning flight stalls at decelerations greater than 1 knot/sec are not required.

(a) "Holding ice"

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Normal stall test altitude

(d) Trim at same initial stall speed factor used for stall speed determination. Decrease speed to stall identification and recover using the same test technique as for the non-contaminated airplane.

(1) High lift devices retracted configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On

(2) Lowest lift take-off configuration: Straight/Power On, Turning/Power Off

(3) Highest lift take-off configuration: Straight/Power Off, Turning/Power On

(4) Highest lift landing configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

3.18 Stall Warning (FAR/JAR 25.207)

3.18.1 Stall warning should be assessed in conjunction with stall speed testing and stall characteristics testing (§ 25.103 and § 25.203 and paragraphs 3.2 and 3.17 of this AC/ACJ) and in tests with faster entry rates.

3.18.2 The following represents an acceptable test program for stall warning in slow down turns of at least 1.5g and at entry rates of at least 2 knot/sec:

(a) "Holding ice"

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Normal stall test altitude

(d) Trim at the same initial stall speed factor used for stall speed determination. Increase speed as necessary prior to establishing at least 1.5g and a deceleration of at least 2 knot/sec. Decrease speed until 1 sec after stall warning and recover using the same test technique as for the non-contaminated airplane.

(1) High lift devices retracted configuration: Power On

(2) Lowest lift take-off configuration: Power Off

(3) Highest lift landing configuration: Power Off

3.18.3 The following represents an acceptable test program for evaluating stall warning margin with the ice accretion prior to normal operation of the ice protection system.

(a) Where the ice protection system is activated as described in A1.2.3(a), paragraphs 3.18.1 and 3.18.2 are applicable with the ice accretion prior to normal system operation.

(b) Where the ice protection system is activated as described in A1.2.3 (b), (c), (d) or (e), it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation, as follows:

In the configurations prescribed in paragraphs (b)(1) and (2), below, trim the airplane at 1.3 V_{SR}. At decelerations of up to 1 knot per second, reduce the speed to stall warning plus 1 second and demonstrate prompt recovery, using the same test technique as for the non-contaminated airplane, without encountering any adverse characteristics. Where stall warning is provided by a different means than for the aircraft without ice accretion and the stall characteristics are demonstrated to be satisfactory, the delay should be at least 3 seconds.

(1) High lift devices retracted configuration: Straight/Power Off

(2) Landing configuration: Straight/Power off.

3.19 Wind Velocities (FAR/JAR 25.237)

3.19.1 Crosswind landings with "Landing Ice" should be evaluated on an opportunity basis.

3.19.2 The results of the steady heading sideslip tests with "Landing Ice" may be used to establish the safe cross wind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated airplane, and the flight characteristics (e.g. control forces and deflections) are similar, then the non-contaminated airplane crosswind component is considered valid.

3.19.3 If the results of the comparison of 3.19.2 are not clearly similar, and in the absence of a more rational analysis, a conservative analysis based on the results of the steady heading sideslip tests may be used to establish the safe crosswind component. The crosswind value may be estimated from:

$$V_{CW} = V_{REF} * \sin(\text{sideslip angle}) / 1.5$$

where V_{CW} is the crosswind component, V_{REF} is the landing reference speed appropriate to a minimum landing weight, and the sideslip angle is that demonstrated at V_{REF} (see paragraph 3.15).

3.20 Vibration and Buffeting (FAR/JAR 25.251)

3.20.1 Qualitative evaluations should be combined with the other testing including speeds up to the maximum speed obtained in the longitudinal stability tests (see paragraph 3.14).

3.20.2 It is also necessary to demonstrate that the aircraft is free from harmful vibration due to residual ice accumulation. This may be done in conjunction with the natural icing tests.

3.20.3 An airplane with pneumatic de-icing boots should be evaluated to V_{DF}/M_{DF} with the de-icing boots operating and not operating. It is not necessary to do this demonstration with ice accretion.

3.21 Natural Icing Conditions

3.21.1 General

Whether the flight test has been performed with artificial ice shapes or in natural icing conditions, additional limited flight test described in this section should be conducted in natural icing conditions. Where flight testing with artificial ice shapes is the primary means for showing compliance, the objective of the tests described in this section is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes.

It is acceptable for some ice to be shed during the testing due to air loads or wing flexure, etc. However, an attempt should be made to accomplish the test maneuvers as soon as possible after exiting the icing cloud to minimize the atmospheric influences on ice shedding.

During any of the maneuvers specified in 3.21.2, the behavior of the airplane should be consistent with that obtained with artificial ice shapes. There should be no unusual control responses or uncommanded airplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

3.21.2 Ice accretion/Maneuvers

(a) Holding scenario

The maneuvers specified in the table below should be carried out with the following ice accretions representative of normal operation of the ice protection system:

- on unprotected parts: A thickness of 3 inches on those parts of the airfoil where the collection efficiency is highest should be the objective. (A thickness of 2 inches is normally a minimum value unless a lesser value is agreed.)

- on protected parts: The ice accretion thickness should be that resulting from normal operation of the ice protection system.

For airplanes with control surfaces which may be susceptible to jamming due to ice accretion (e.g. elevator horns exposed to the air flow), the holding speed that is critical with respect to this ice accretion should be used.

Configuration	c.g.	Trim speed	Maneuver
Flaps up, gear up	Optional (aft range)	Holding	Level, 40° banked turn Bank-to-bank rapid roll, 30° - 30° Speedbrake extension, retraction Full straight stall
Flaps in intermediate positions, gear up	Optional (aft range)	1.4 V_S or 1.3 V_{SR}	Deceleration to stall warning
Landing flaps, gear down	Optional (aft range)	V_{REF}	Level, 40° banked turn Bank-to-bank rapid roll, 30° - 30° Speedbrake extension, retraction (If approved) Full straight stall

(b) Approach/Landing Scenario

The maneuvers specified in the table below should be carried out with successive accretions in different configurations on unprotected surfaces such that the final ice accretion represents the sum of the amounts accreted in each configuration: -

Ice accretion thickness (*)	Configuration	c.g.	Trim speed	Maneuver
first 0.5 in	Flaps up, gear up	Optional (aft range)	Holding	No specific test

additional 0.25 in	First intermediate flaps, gear up	Optional (aft range)	Holding	Level 40° banked turn, Bank-to-bank rapid roll, 30°- 30°, speed brake extension and retraction (if approved), deceleration to stall warning
additional 0.25 in	Further intermediate flaps, gear up (as applicable)	Optional (aft range)	1.4 V_S or 1.3 V_{SR}	Bank-to-bank rapid roll, 30° - 30°, speed brake extension and retraction (if approved), deceleration to stall warning
additional 0.25 in	Landing flaps, gear down	Optional (aft range)	V_{REF}	Bank-to-bank rapid roll, 30° - 30°, speed brake extension and retraction (if approved), bank to 40°, Full straight stall

(*) The indicated thickness is that obtained on the parts of the unprotected airfoil with the highest collection efficiency.

3.21.3 For airplanes with unpowered elevator controls, in the absence of an agreed substantiation of the criticality of the artificial ice shape used to demonstrate compliance with the controllability requirement the pushover test of paragraph 3.9.3 should be repeated with a thin accretion of natural ice.

3.21.4 Existing propeller speed limits, or if required, revised propeller speed limits for flight in icing, should be verified by flight tests in natural icing conditions.

3.22 Failure Conditions (FAR/JAR 25.1309)

3.22.1 For failure conditions which are annunciated to the crew, credit may be taken for the established operating procedures following the failure.

3.22.2 In addition to a general qualitative evaluation, the following test program (modified as necessary to reflect the specific operating procedures) should be carried out for the most critical probable failure condition where the associated procedure requires the airplane to exit the icing condition:

(a) The critical ice accretion on the unprotected surfaces (and on the normally protected surfaces that are still functioning following the segmental failure of a cyclical de-ice system), appropriate to normal ice protection system operation during the holding flight phase, plus the critical ice accretion on the normally protected surfaces that are no longer protected as a result of the failure condition.

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at specified speed. Conduct 30 degrees banked turns left and right with normal reversals. Conduct pull up to 1.5g and pushover to 0.5g.

(1) High lift devices retracted configuration (or holding configuration if different), holding speed, thrust for level flight

In addition deploy and retract deceleration devices

(2) Approach configuration, approach speed, thrust for level flight

(3) Landing configuration, landing speed, thrust for landing approach (limit pull up to 1.3g).

In addition conduct steady heading sideslips to angle of sideslip appropriate to type and landing procedure.

(d) Trim at estimated 1.3 V_{SR}. Decrease speed to stall warning plus 1 second and demonstrate prompt recovery using the same test technique as for the non-contaminated airplane. Natural stall warning is acceptable for the failure case.

(1) High lift devices retracted configuration: Straight/Power Off

(2) Landing configuration: Straight/Power off.

(e) Approach and go-around with all engines operating using the recommended procedure

(f) Approach and landing with all engines operating (unless the one-engine-inoperative condition results in a more critical probable failure condition) using the recommended procedure.

3.22.3 For improbable failure conditions, flight test may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) is commensurate with the failure probability or to verify the results of analyses and/or wind tunnel tests. The extent of any required flight test should be similar to that described in paragraph 3.22.2, or as agreed with the certification authority for the specific failure condition.

APPENDIX 1

AIRFRAME ICE ACCRETION

A1.1 General

The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered include:

- the flight conditions e.g. airplane configuration, speed, angle of attack, altitude, and -

- the icing conditions of Appendix C, e.g., temperature, liquid water content, mean effective drop diameter.

Minority Positions

ALPA submitted a minority position that supports a more definitive description of the parameters that determine the "critical" ice accretion for each airplane configuration.

[For details of Minority Positions, refer to the Draft NPRM.]

A1.2 Operative Ice Protection System

A1.2.1 All flight phases except take-off

For unprotected parts, the ice accretion to be considered should be determined in accordance with FAR/JAR 25.1419.

Unprotected parts consist of the unprotected airfoil leading edges and all unprotected airframe parts on which ice may accrete. The effect of ice accretion on protuberances such as antennae or flap hinge fairings need not normally be investigated. However airplanes which are characterized by unusual unprotected airframe protuberances, e.g., fixed landing gear, large engine pylons, or exposed control surface horns or winglets, etc., may experience significant additional effects which should therefore be taken into consideration.

For Holding Ice, certification experience has shown that the amount of ice on the most critical unprotected main airfoil surface (e.g. wing, horizontal or vertical stabilizers) to be considered need not exceed a pinnacle height of typically 3 inches (75 mm) in a plane in the direction of flight. For other unprotected main surfaces an analysis may be performed to determine the maximum ice accretion associated with this maximum pinnacle height. In the absence of such an acceptable analysis a uniform pinnacle height of 3 inches (75 mm) should be assumed. The shape and texture of the ice are important and should be agreed with the certification authority.

For protected parts the ice protection systems are normally assumed to be operative. However, the applicant should consider the effect of ice accretion on the protected surfaces which results from:

(a) The rest time of a de-icing cycle. Performance may be established on the basis of a representative intercycle ice accretion for normal operation of the deicing system (consideration should also be given to the effects of any residual ice accretion that is not shed). The average drag increment determined over the de-icing cycle may be used for performance calculations.

(b) Runback ice which occurs on or downstream of the protected surface.

(c) Ice accretion prior to normal operation of the ice protection system (see paragraph A1.2.3).

A1.2.2 Take-off phase

For both unprotected and protected parts, the ice accretion identified in Appendix C to FAR/JAR-25 for the take-off phase may be determined by calculation, assuming the Takeoff Maximum icing conditions defined in Appendix C, and:

- that airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off, and -
- the ice accretion starts at liftoff,
- the critical ratio of thrust/power-to-weight,
- failure of the critical engine occurs at V_{EF}, and
- crew activation of the ice protection system in accordance with an AFM procedure, except that after commencement of the take-off roll no crew action to activate the ice protection system should be assumed to occur until the airplane is 400 ft above the take-off surface.

The ice accretions identified in Appendix C to FAR/JAR-25 for the take-off phase are:

- Take-off ice: The most critical ice accretion between liftoff and 400 ft above the takeoff surface, assuming accretion starts at liftoff in the icing environment.

- Final Take-off ice: The most critical ice accretion between 400 ft and 1500 ft above the take-off surface, assuming accretion starts at liftoff in the icing environment.

A1.2.3 Ice accretion prior to normal system operation

Ice protection systems are normally operated as anti-icing systems (i.e. designed to prevent ice accretion on the protected surface) or deicing systems (i.e. designed to remove ice from the protected surface). In some cases, systems may be operated as anti-icing or deicing systems depending on the phase of flight. Operation of ice protection systems can also include a resetting of stall warning and/or stall identification system (e.g. stick pusher) activation thresholds.

The Airplane Flight Manual contains the operating limitations and operating procedures established by the applicant. Since ice protection systems are normally only operated when icing conditions are encountered or when airframe ice is detected, means of flight crew determination of icing conditions and/or airframe ice should be considered in determining the ice accretion prior to normal system operation. This includes the ice accretion appropriate to the specified means of identification of icing conditions and an additional ice accretion, represented by a time in the Continuous Maximum icing conditions of Appendix C, to account for crew delay in either identifying the conditions and activating the ice protection systems ((a), (b) and (c) below), or activating the ice protection system following indication from an ice detection system ((d) below). In addition the system response time should be considered. System response time is defined as the time interval between activation of the ice protection system and the performance of its intended function, e.g. for a thermal ice protection system, the time to heat the surface and remove the ice.

Minority Positions

ALPA submitted a minority position that questions the applicability of a 30 second delay time to an ice detection method that requires the pilot to look outside the cockpit..

[For details of Minority Positions, refer to the Draft NPRM.]

The following examples indicate the ice accretion to be considered on the unprotected and normally protected aerodynamic surfaces:

(a) If normal operation of any ice protection system is dependent on visual recognition of a specified ice accretion on a reference surface (e.g. ice accretion probe, wing leading edge), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable crew delays in recognition of the ice accreted and operation of the system, determined as follows:

(1) the specified accretion, plus
(2) the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a), plus
(3) the ice accretion during the system response time.

(b) If normal operation of any ice protection system is dependent on visual recognition of the first indication of ice accretion on a reference surface (e.g. ice accretion probe), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable crew delays in recognition of the ice accreted and operation of the system, determined as follows:

(1) the ice accretion corresponding to first indication on the reference surface, plus

(2) the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a), plus

(3) the ice accretion during the system response time.

(c) If normal operation of any ice protection system is dependent upon pilot identification of icing conditions as defined by an appropriate static or total air temperature and visible moisture conditions, the ice accretion should not be less than that corresponding to the ice accreted during probable crew delays in recognition of the icing conditions and operation of the system, determined as follows

(1) the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a), plus
(2) the ice accretion during the system response time.

(d) If normal operation of any ice protection system is dependent on pilot action following indication from an ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to indication from the ice detection system, probable crew delays in activating the ice protection system and operation of the system, determined as follows

(1) the ice accretion corresponding to the time between entry into the icing conditions and indication from the ice detection system, plus

(2) the ice accretion equivalent to ten seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a) plus

(3) the ice accretion during the system response time.

(e) If normal operation of any ice protection system is automatic following indication from an ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to indication from the ice protection system and operation of the system, determined as follows:

(1) the ice accretion on the protected surfaces corresponding to the time between entry into the icing conditions and activation of the system, plus

(2) the ice accretion during the system response time.

A1.3 Ice Protection System Failure Cases

A1.3.1 Unprotected parts

The same accretion as in paragraph A1.2.1 is applicable.

A1.3.2 Protected parts following system failure

(a) .In the case where the failure condition is not annunciated, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

(b) In the case where the failure condition is annunciated and the associated procedure does not require the airplane to exit icing conditions, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

(c) In the case where the failure condition is annunciated and the associated procedure requires the airplane to exit icing conditions as soon as possible, the ice accretion on normally protected parts where the ice protection has failed, should be taken as one-half of the accretion specified for unprotected parts unless another value is agreed by the certifying authority.

APPENDIX 2

ARTIFICIAL ICE SHAPES

A2.1 General

The artificial ice shapes used for flight testing should be those which have the most adverse effects on handling characteristics. If analytical data show that other reasonably expected ice shapes could be generated which could produce higher performance decrements, then the ice shape having the most adverse effect on handling characteristics may be used for performance tests provided that any difference in performance can be conservatively taken into account.

The artificial shapes should be representative of natural icing conditions in terms of location, general shape, thickness and texture. Following determination of the form and surface texture of the ice shape under paragraph A2.2, a surface roughness for the shape should be agreed with the Authority under paragraph A2.3 as being representative of natural ice accretion.

"Sandpaper ice" is addressed in paragraph A2.3.

A2.2 Shape and Texture of Artificial Ice

The shape and texture of the artificial ice should be established and substantiated by agreed methods. Common practices include:

- use of computer codes
- flight in measured natural icing conditions
- icing wind tunnel tests, and
- flight in a controlled simulated icing cloud (e.g. from an icing tanker).

In the absence of another agreed definition of texture the following may be used:

For small amounts of ice (for example the amount of ice accreted during a de-icing system rest time), the roughness should be typically:

- roughness height: 1 mm
- particle density: 8 to 10/cm^2

For large amounts of ice (for example on an unprotected, exposed surface), the roughness should be typically:

- roughness height: 3 mm
- particle density: 8 to 10/cm^2

A2.3 "Sandpaper ice"

"Sandpaper ice" is the most critical thin, rough layer of ice. Any representation of "Sandpaper ice" (e.g. carborundum paper no. 40) should be agreed by the certifying authority. The spanwise and chordwise coverage should be consistent with the areas of ice accretion determined for the conditions of FAR/JAR-25 Appendix C except that, for the zero g pushover maneuver of paragraph 3.9.3, the "Sandpaper ice" may be restricted to the horizontal stabilizer if this can be shown to be conservative.

APPENDIX 3

DESIGN FEATURES

A3.1 Airplane Configuration and Ancestry

An important design feature of an overall airplane configuration that can affect performance, controllability and maneuverability is its size. In addition, the safety record of the airplane's closely-related ancestors may be taken into consideration.

A3.1.1 Size

The size of an airplane determines the sensitivity of its flight characteristics to ice thickness and roughness. The relative effect of a given ice height (or ice roughness height) decreases as airplane size increases.

A3.1.2 Ancestors

If a closely related ancestor airplane was certified for flight in icing conditions, its safety record may be used to evaluate its general arrangement and systems integration.

A3.2 Wing

Design features of a wing that can affect performance, controllability, and maneuverability include aerofoil type, leading edge devices and stall protection devices.

A3.2.1 Aerofoil

Aerofoils with significant natural laminar flow when non-contaminated may show large changes in lift and drag with ice. Conventional aerofoils operating at high Reynolds numbers make the transition to turbulent flow near the leading edge when non-contaminated, thus reducing the adverse effects of the ice.

A3.2.2 Leading Edge Device

The presence of a leading edge device (such as a slat) reduces the percentage decrease in $C_{L_{max}}$ due to ice by increasing the overall level of C_L. Gapping the slat may improve the situation further. Leading edge devices can also reduce the loss in angle of attack at stall due to ice.

A3.2.3 Stall Protection Device

An airplane with an automatic slat-gapping device may generate a greater $C_{L_{max}}$ with ice than the certified $C_{L_{max}}$ with the slat sealed and a non-contaminated leading edge. This may provide effective protection against degradation in stall performance or characteristics.

A3.2.4 Lateral Control

The effectiveness of the lateral control system in icing conditions can be evaluated by comparison with closely related ancestor airplanes.

A3.3 Empennage

The effects of size and aerofoil type also apply to the horizontal and vertical tails. Other design features include tailplane sizing philosophy, aerofoil design, trimmable stabilizer, and control surface actuation. Since tails are usually not equipped with leading edge devices, the effects of ice on tail aerodynamics are similar to those on a wing with no leading edge devices. However, these effects usually result in changes to airplane handling and/or control characteristics rather than degraded performance.

A3.3.1 Tail Sizing

The effect on airplane handling characteristics depends on the tailplane design philosophy. The tailplane may be designed and sized to provide full functionality in icing conditions without ice protection, or it may be designed with a de-icing or anti-icing system.

A3.3.2 Horizontal Stabilizer Design

Cambered aerofoils and trimmable stabilizers may reduce the susceptibility and consequences of elevator hinge moment reversal due to ice-induced tailplane stall.

A3.3.3 Control Surface Actuation

Hydraulically powered irreversible elevator controls are not affected by ice-induced aerodynamic hinge moment reversal.

A3.3.4 Control Surface Size

For mechanical elevator controls the size of the surface significantly affects the control force due to an ice-induced aerodynamic hinge moment reversal. Small surfaces are less susceptible to control difficulties for given hinge moment coefficients.

A3.3.5 Vertical Stabilizer Design

The effectiveness of the vertical stabilizer in icing conditions can be evaluated by comparison with closely-related ancestor airplanes.

A3.4 Aerodynamic Balancing of Flight Control Surfaces

The aerodynamic balance of unpowered or boosted reversible flight control surfaces is an important design feature to consider. The design should be carefully evaluated to account for the effects of ice accretion on flight control system hinge moment characteristics. Closely balanced controls may be vulnerable to overbalance in icing. The effect of ice in front of the control surface, or on the surface, may upset the balance of hinge moments leading to either increased positive force gradients or negative force gradients.

This feature is particularly important with respect to lateral flight control systems when large aileron hinge moments are balanced by equally large hinge moments on the opposite aileron. Any asymmetric disturbance in flow which affects this critical balance can lead to a sudden uncommanded deflection of the control. This auto deflection, in extreme cases, may be to the control stops.

A3.5 Ice Protection/Detection System

The ice protection/detection system design philosophy may include design features that reduce the ice accretion on the wing and/or tailplane.

A3.4.1 Wing Ice Protection/Detection

An ice detection system that activates a wing de-icing system may ensure that there is no significant ice accretion on wings that are susceptible to performance losses with small amounts of ice.

If the entire wing leading edge is not protected, the part that is protected may be selected to provide good handling characteristics at stall, with an acceptable performance degradation.

A3.4.2 Tail Ice Protection/Detection

An ice detection system may activate a tailplane de-icing system on airplanes that do not have visible cues for system operation.

An ice protection system on the unshielded aerodynamic balances of airplanes with unpowered reversible controls can reduce the risk of ice-induced aerodynamic hinge moment reversal.